VI.7. ECONOMIC IMPACT OF POPULATION LOSSES

The economic losses associated with the potential RIS population losses due to entrainment at R.P. Smith were estimated from historical and present dollar values of the individual recreational fisheries of the freshwater Potomac River system, as determined by creel census (Ref. VI-10). Figure VI-4 shows the estimation method diagramatically. The key quantities used in the calculation were the long-term mean economic values of the freshwater Potomac River fishery between RM 125-285 (approximately $100,000, Ref. VI-11), the values of individual fisheries (Table VI-8), and the losses of equivalent RIS adults (Table VI-5). The proportional value loss (P_2) to the freshwater Potomac recreational fishery due to entrainment of species i at R.P. Smith is:

$$P_2 = P_1 \cdot V_i / \sum_i V_i \qquad (6\text{-}10)$$

where

P_1 = equivalent RIS adult losses of species i due to entrainment at R.P. Smith

V_i = mean annual dollar value of species i in the freshwater Potomac (RM 125-285) recreational fishery

$\sum_i V_i$ = total mean annual dollar value of the freshwater Potomac recreational fishery.

The proportional economic impact of all species losses due to entrainment at R.P. Smith is then:

$$E_2 = \sum_i P_{2i}. \qquad (6\text{-}11)$$

Table VI-9 shows the estimated proportional economic losses (P_2) resulting from entrainment mortalities at R.P. Smith. As shown, only the loss to the channel catfish fishery is estimated at greater than 0.1%; the dollar value of this loss is approximately $300. The total of all potential population losses due to entrainment results in an economic penalty of slightly more than $400/year.

VI.8. ECOLOGICAL IMPACT OF POPULATION LOSSES

The loss of portions of RIS life-stage populations from the freshwater Potomac system could alter the energy flow pattern and trophic dynamics of the lotic ecosystem. Impact at the ecosystem level can be simplistically evaluated as the proportion of system net primary production that would not be utilized if segments of the RIS life-stage populations were eliminated.

The computational logic used to estimate this quantity, and thus the ecological impact of the population losses due to entrainment at R.P. Smith, is shown in Figure VI-5. The trophic structure and feeding dynamics in the Piedmont area of the Potomac River, the distributions (densities) of the RIS life stages over the trophic structure, and the estimated assimilation efficiencies of each trophic level are the key variables necessary for calculating the proportional intakes of system net productivity by each RIS life stage.

The trophic structure of the Piedmont Potomac system is assumed to consist of six levels representing primary producers, herbivores, detritivores, and various carnivores. Reproductive products (i.e., eggs) generally can be ignored in this scheme as they do not remove any substantial portion of the system's biomass or energy flow in their initial development. All remaining life stages (i.e., larva, juvenile, adult) are included in the calculation. Based on feeding rates, community and trophic level composition, and an assumed 10% assimilation efficiency between trophic levels, the proportion of "unutilized" system net productivity (P_3) resulting from entrainment losses may be determined as:

$$P_3 = \frac{\sum_x [1 - (1-P_{ij=1})\cdots(1-P_{ij+n})] \cdot (I_{ijx} \cdot A^{-x} \cdot NPP)}{\sum_x (A^{-x} \cdot NPP)} \qquad (6\text{-}12)$$

where

- x = index defining the position of the life stage in the Piedmont Potomac River trophic structure
- P_{ij} = calculated proportional loss of life-stage population j of species i due to entrainment at R.P. Smith
- I_{ijx} = proportional intake of system net productivity of trophic level (x-1) by life stage j of species i at trophic level x
- A^{-x} = assimilation efficiency of trophic level x (assumed to be 10^{-x})
- NPP = system net primary productivity.

The ecological effect of all species losses due to entrainment may then be expressed as:

$$E_3 = \sum_i P_{3i}. \tag{6-13}$$

The estimates of the "unutilized" percentages of system net productivity (P_3) calculated from Eq. (6-12) are given in Table VI-10. From Eq. (6-13), the total loss of ecological productivity due to entrainment loss at R.P. Smith (E_3) is 0.09 grams per 100 grams of net system production. As can be seen, the proportional potential total ecological impact of the RIS population losses in the Piedmont Potomac system is smaller than the potential economic impact, primarily because the potential RIS population losses of species occupying lower trophic levels are relatively small (i.e., < 1.0%). Normalized for the proportion of net primary production eventually utilized by finfish life stages (40%), the net ecological impact of entrainment losses is less than 0.25%.

VI.9. DISCUSSION

The calculated potential population losses due to entrainment at the R.P. Smith SES are in the valid range of linearization.

There are no species for which potential entrainment losses appear to be significant ($P_1 > 1.0$). The estimated economic and ecological impacts due to the potential entrainment mortalities are acceptable. The $400 annual loss to the recreational fishery, due primarily to potential channel catfish losses, is minimal compared to the total annual value for the fisheries of about $100,000 (Ref. VI-11). The overall projected ecological impact on system-wide energy flow is less than 0.1 grams per 100 grams of system net primary production.

Percentage economic impact (0.4%) is significantly higher than percentage ecological impact (0.09%) because channel catfish and redbreast sunfish account for about 95% of this economic loss whereas 85% of the system energy loss is due to losses in forage species (i.e., suckers and shiners). It appears clear from this analysis that there are no appreciable population, economic, or ecological impacts due to entrainment mortalities at the R.P. Smith SES.

Table VI-1. Representative important species (RIS) in the Appalachian Highlands-Piedmont area of the Potomac River for which impacts were assessed with the entrainment algorithm.

Common Name	Scientific Name
Spottail shiner	Notropis hudsonius
White sucker	Catostomus commersoni
Redbreast sunfish	Lepomis auritus
Other sunfish (aggregate)*	Lepomis spp.
Channel catfish	Ictalurus punctatus
Smallmouth bass	Micropterus dolomieui
Largemouth bass	Micropterus salmoides
Caddisflies	Trichoptera
Stoneflies	Plecoptera
Mayflies	Ephemeroptera
Spotfin shiner (non-RIS)	Notropis spilopterus
Golden redhorse (non-RIS)	Moxostoma erythrurum

*Due to the difficulty of differentiating eggs and larvae among sunfish, the following species are grouped together: pumpkinseed (Lepomis gibbosus), bluegill (L. macrochirus), green sunfish (L. cyanellus), and longear sunfish (L. megalotis).

Table VI-2. Values of physical parameters for calculating entrainment probabilities at the R.P. Smith SES from April-August.

Input	Value
Mean total discharge (Q_T)	165.0 m^3/s (a)
Cooling system flow (Q_P)	4.5 m^3/s (b)
Cooling system flow - Unit 4 (Q_P')	2.6 m^3/s (b)
Recirculation rate - Units 3 and 4 (R)	0.0 (b)
Mean cross-sectional area of receiving water: April-August (A_T)	123.1 m^2 (b)
Mean maximal cross-sectional area of the excess 2C isotherm: April-August (A_C)	28.0 m^2 (b)

(a) Ref. VI-9.

(b) Ref. VI-1 or computed from Ref. VI-1.

Table VI-3. Mean finfish life-stage densities at nearshore (NS) regions in the upper Potomac River and for the Appalachian Highlands-Piedmont region of the Potomac (PP) for April-August.

	Density (no./1,000 m^3)			
	Larvae		Juveniles	
	NS[a]	PP[b]	NS[a]	PP[a]
Spottail shiner	58.6	44.1	1.8	1.4
Golden redhorse	44.9	22.8	6.8	3.5
Channel catfish	13.0	10.0	0.5	0.7
Redbreast sunfish	0.5	0.5	0.7	0.5
Other sunfish	0.8	0.8	0.50	0.3
Smallmouth bass	(c)	1.8	0.07	0.07
Largemouth bass	(c)	1.5	0.03	0.03
Spotfin shiner	21.2	89.1	6.4	11.6

(a) Extrapolated from Refs. VI-1 through VI-5.

(b) Extrapolated from Ref. VI-6.

(c) Density of larvae not measured but early life stages (e.g., adhesive eggs, nests, larvae with cement glands or in nests) of these species are not generally found in the water column.

Table VI-4. Developmental times and length of times entrainable life stages remain in the Appalachian Highlands-Piedmont region of the Potomac River.

Species	Length of Time Entrainable (days)			Developmental Time (days)		
	Eggs	Larvae[a]	Post-Larvae[b]	Eggs	Larvae	Post-Larvae
Spottail shiner	< 7	20	60	60	52	60
Golden redhorse	17	20	50	45	60	60
Redbreast sunfish	10	30	90	25	45	90
Other sunfish	10	30	75	30	30	75
Channel catfish	5-10	35	45	30	50	70
Brown bullhead	5-14	30	60	30	60	60
Smallmouth bass	5	25	70	40	30	60
Largemouth bass	4	30	75	40	35	50
Spotfin shiner	< 7	20	60	60	60	60
Bluntnose minnow	2	40	100	60	60	60

[a] Developmental time from hatch to approximately 10-20 mm.

[b] Developmental time from about 20 mm to 50 mm.

Table VI-5. Potential percentage losses of RIS life stages[a] due to cooling system and plume entrainment at the R.P. Smith SES.

Species	Larvae (%)	Juveniles (%)	Total Equivalent Adults (%)
Channel catfish	0.5	<0.1[b]	0.6
Spottail shiner	0.5	<0.1	0.5
Redbreast sunfish	0.4	<0.1[c]	0.4
Other sunfish	0.4	<0.1[c]	0.4
Smallmouth bass	0.0	<0.1	<0.1
Largemouth bass	0.0	<0.1	<0.1
Golden redhorse (non-RIS)	0.8	<0.1[d]	0.9
Spotfin shiner (non-RIS)	<0.1	<0.1	0.1

[a] Egg losses not calculated because most eggs adhesive or laid in nests.

[b] Only 15% of juvenile catfish are of entrainable size (< 50 mm) (calculated from Ref. VI 5).

[c] Only 10% of juvenile sunfish are of entrainable size (< 50 mm) (calculated from Ref. VI-5).

[d] Only 10% of juvenile suckers are of entrainable size (< 50 mm) (calculated from Ref. VI 5).

Table VI-6. Mean standing stocks and drift densities of RIS macroinvertebrates in the vicinity of the R.P. Smith SES (PS) and the Appalachian Highlands-Piedmont Potomac (PP) region in August.

Taxa Groups	Densities		
	Standing Stock (No./m^2)		Drifting (No./100m^3)
	PS[a]	PP[b]	PS[a]
Mayflies	1,722	2,356	449
Caddisflies	2,205	1,734	61
Stoneflies[c]	0.0	0.0	0.0

[a] Ref. VI-4.

[b] Refs. VI-4, VI-5.

[c] No stoneflies were taken in standing stock drift samples (Refs. VI-4, VI-5).

Table VI-7. Potential percentage losses of RIS insect groups due to R.P. Smith cooling system and plume entrainment of drifting insects (P_K and W_K, respectively) and continual plume exposure while in sediments (W_K').

Insect Group	P_K	W_K (%)	W_K'	P_1
Mayflies	6.8×10^{-3}	4.3×10^{-2}	3.4×10^{-2}	0.08
Caddisflies	1.3×10^{-4}	1.2×10^{-3}	1.2×10^{-2}	0.01

Table VI-8. Composition of recreational fishery for the Piedmont area of the Potomac River.

Species	Proportional Catch[a] (lb/1,000 pounds)	Annual Value[b] (dollars)
Channel catfish	711.9	43,900
Blue catfish	12.9	800
Yellow bullhead	20.6	1,200
Brown bullhead	1.5	100
Smallmouth bass	86.1	26,600
Largemouth bass	6.8	1,500
Black crappie	15.2	1,700
Bluegill	18.3	3,600
Pumpkinseed	11.4	
Redbreast sunfish	91.5	17,900
Carp	19.0	300
Suckers	2.2	100
Golden redhorse	0.8	50
Yellow perch	1.5	100
Total	1,000	100,050

[a] Based on Ref. VI-10.

[b] Based on COMAR Regulation and Ref. VI-11.

Table VI-9. Percentage of economic losses (P_2) due to RIS entrainment losses (P_1) at the R.P. Smith SES.

Species	P_1	P_2
Golden redhorse (non-RIS)	0.8	0.0
Channel catfish	0.6	0.3
Spottail shiner	0.5	0.0
Redbreast sunfish	0.4	<0.1
Other sunfish	0.4	<0.1
Spotfin shiner (non-RIS)	0.1	0.0
Smallmouth bass	<0.1	<0.1
Largemouth bass	<0.1	<0.1
Mayflies	<0.1	0.0
Caddisflies	<0.1	0.0
		$E_2 = 0.4$ ($400/year)

Table VI-10. Percent system energy losses (P_3) and economic losses (P_2) due to entrainment losses (P_1) at R.P. Smith SES.

Species	P_1	P_2	P_3
Golden redhorse (non-RIS)	0.8	0.0	0.051
Channel catfish	0.6	0.3	0.004
Spottail shiner	0.5	0.0	0.010
Redbreast sunfish	0.4	<0.1	<0.001
Other sunfish	0.4	<0.1	0.001
Spotfin shiner (non-RIS)	0.1	0.0	0.011
Smallmouth bass	<0.1	<0.1	<0.001
Largemouth bass	<0.1	<0.1	<0.001
Mayflies	<0.1	0.0	0.007
Caddisflies	<0.1	0.0	0.001
		E_2 = 0.4 ($400/yr)	E_2 = 0.085 (0.09 g/100 g NPP)

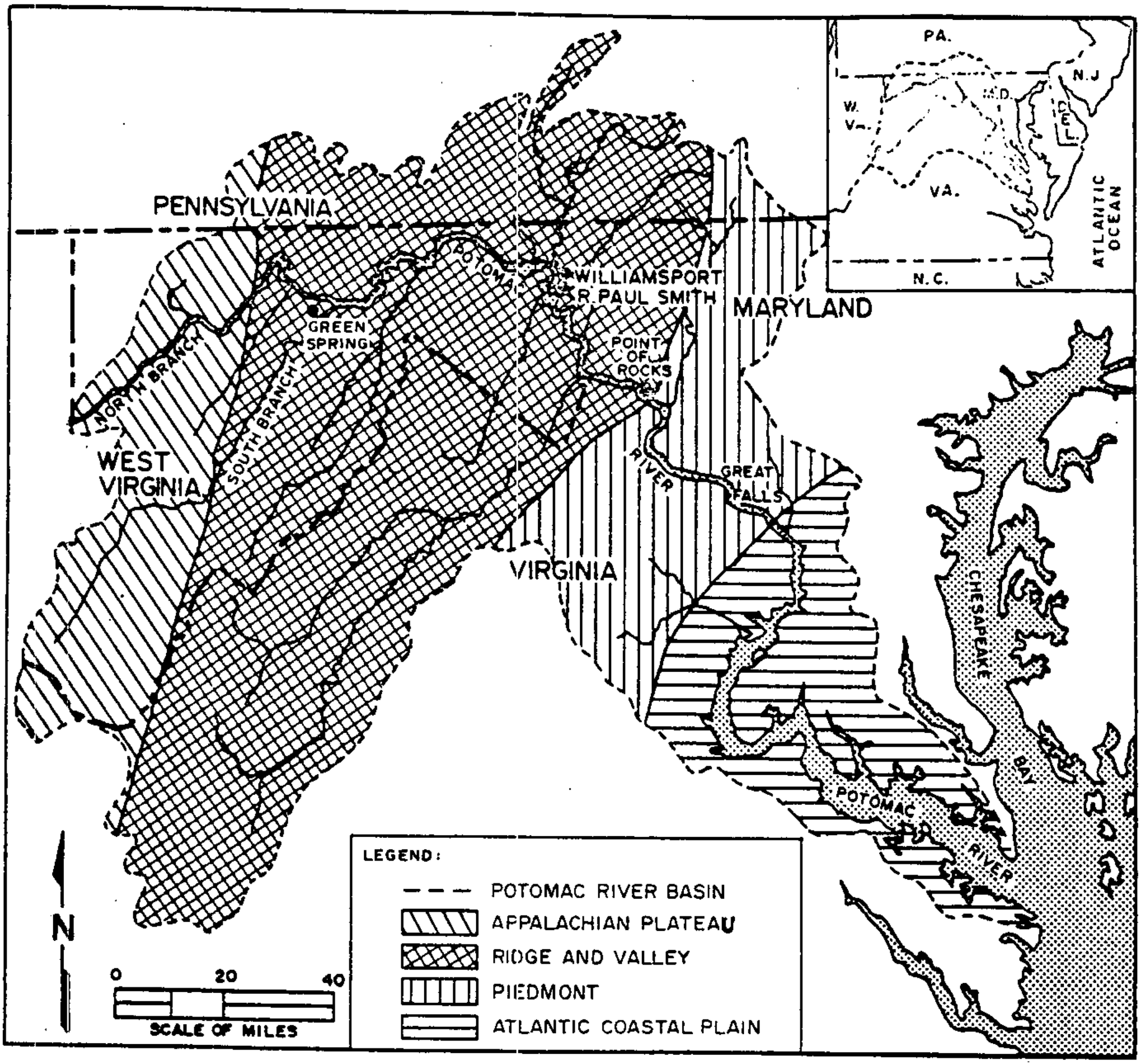

Figure VI-1. Geological regions of the Potomac River basin.

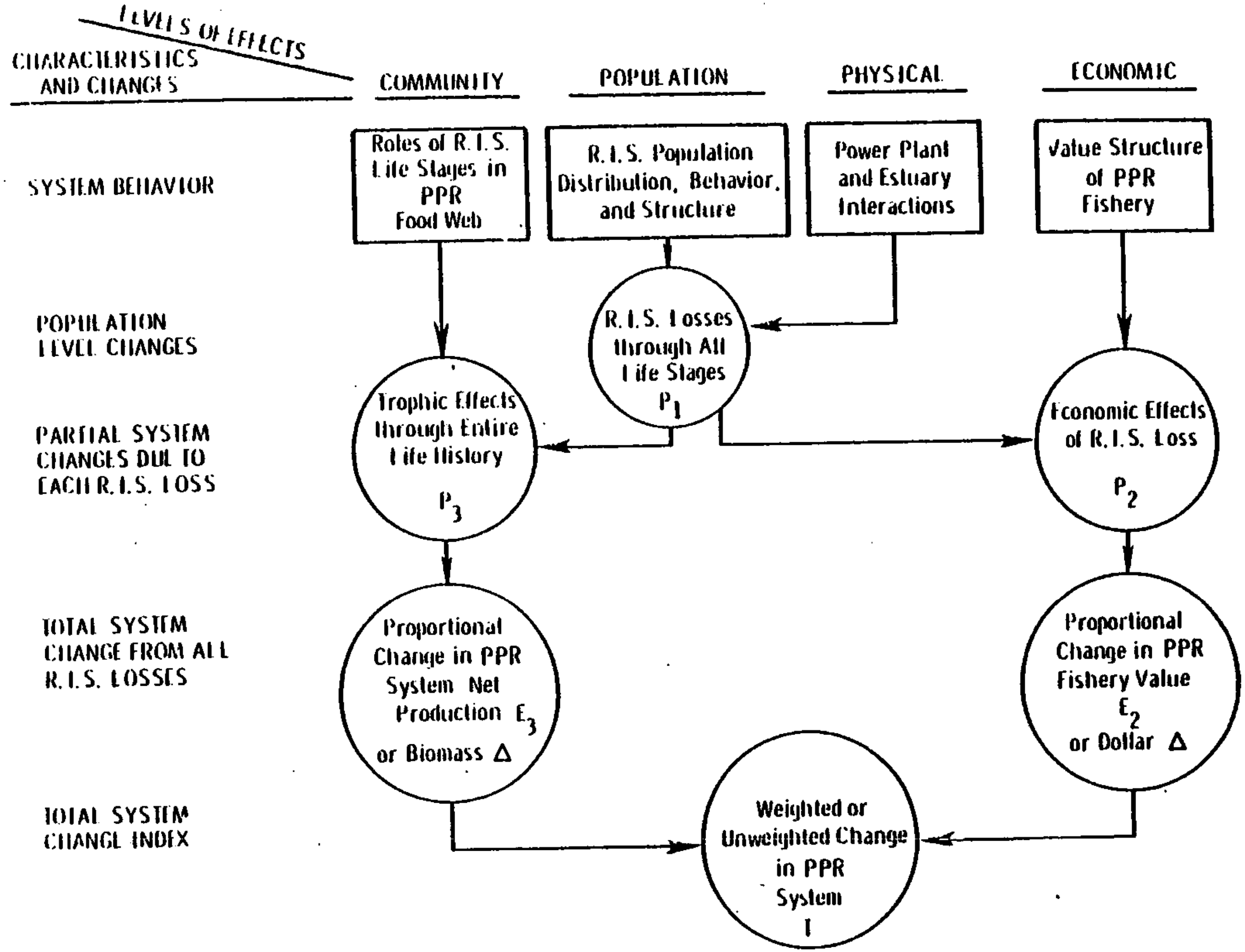

Figure VI-2. General computational scheme for evaluating entrainment at the R.P. Smith SES in the Appalachian Highlands-Piedmont area of the Potomac River (PPR). See text for explanation of symbols.

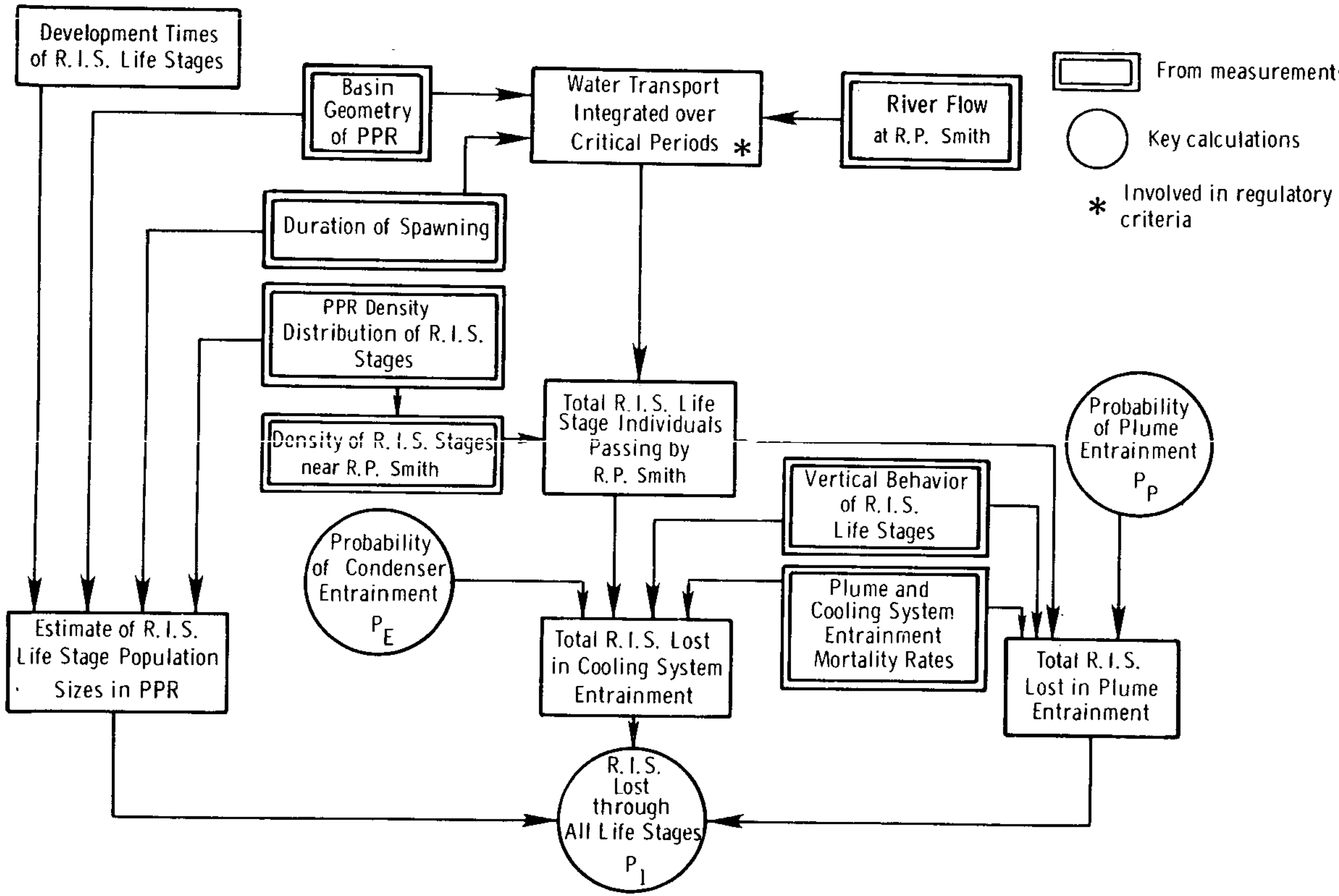

Figure VI-3. General scheme for estimating population losses due to cooling system and plume entrainment at R.P. Smith SES on the Piedmont Potomac River (PPR). See text for explanation of symbols.

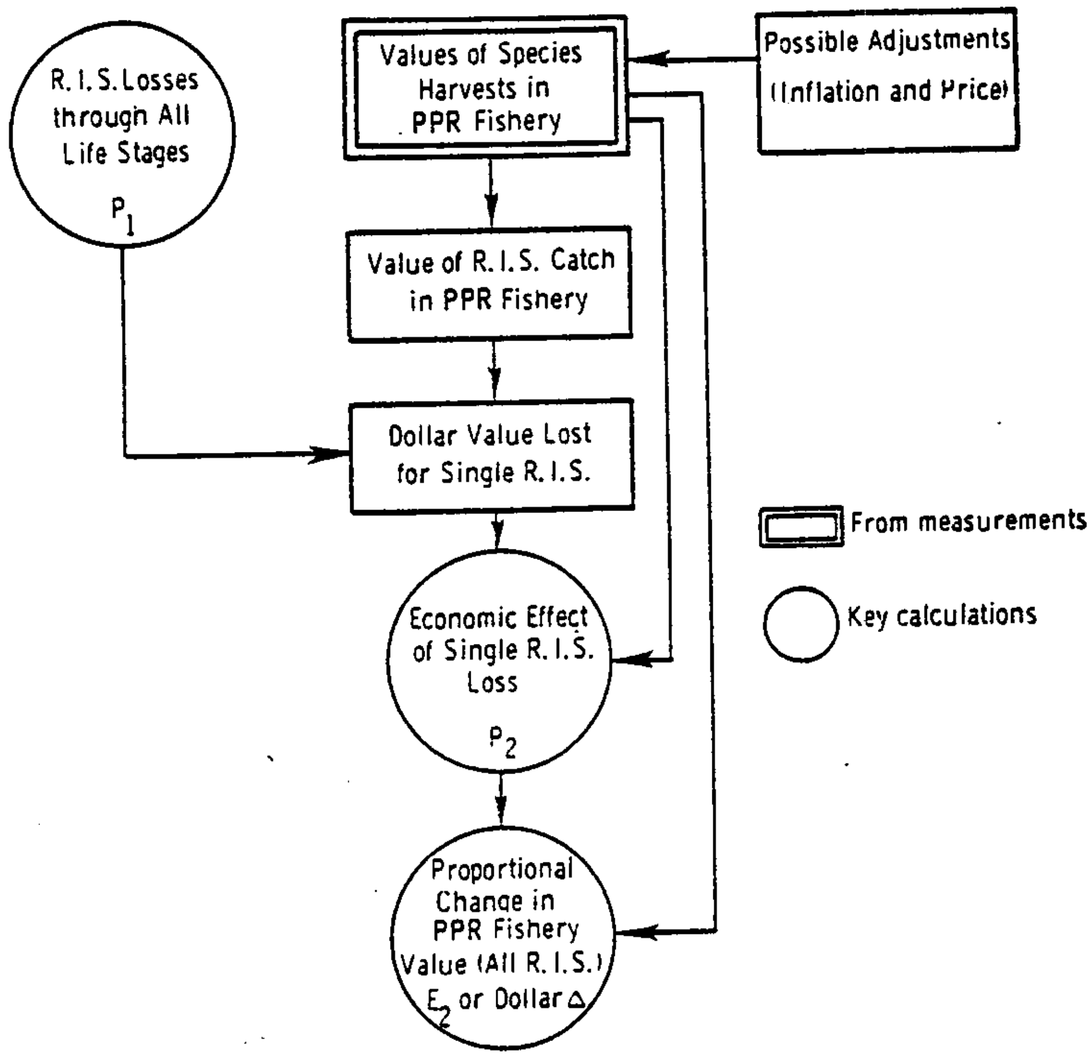

Figure VI-4. General scheme for estimating the economic impact associated with population losses due to entrainment at R.P. Smith SES in the Piedmont area of the Potomac River (PPR). See text for explanation of symbols.

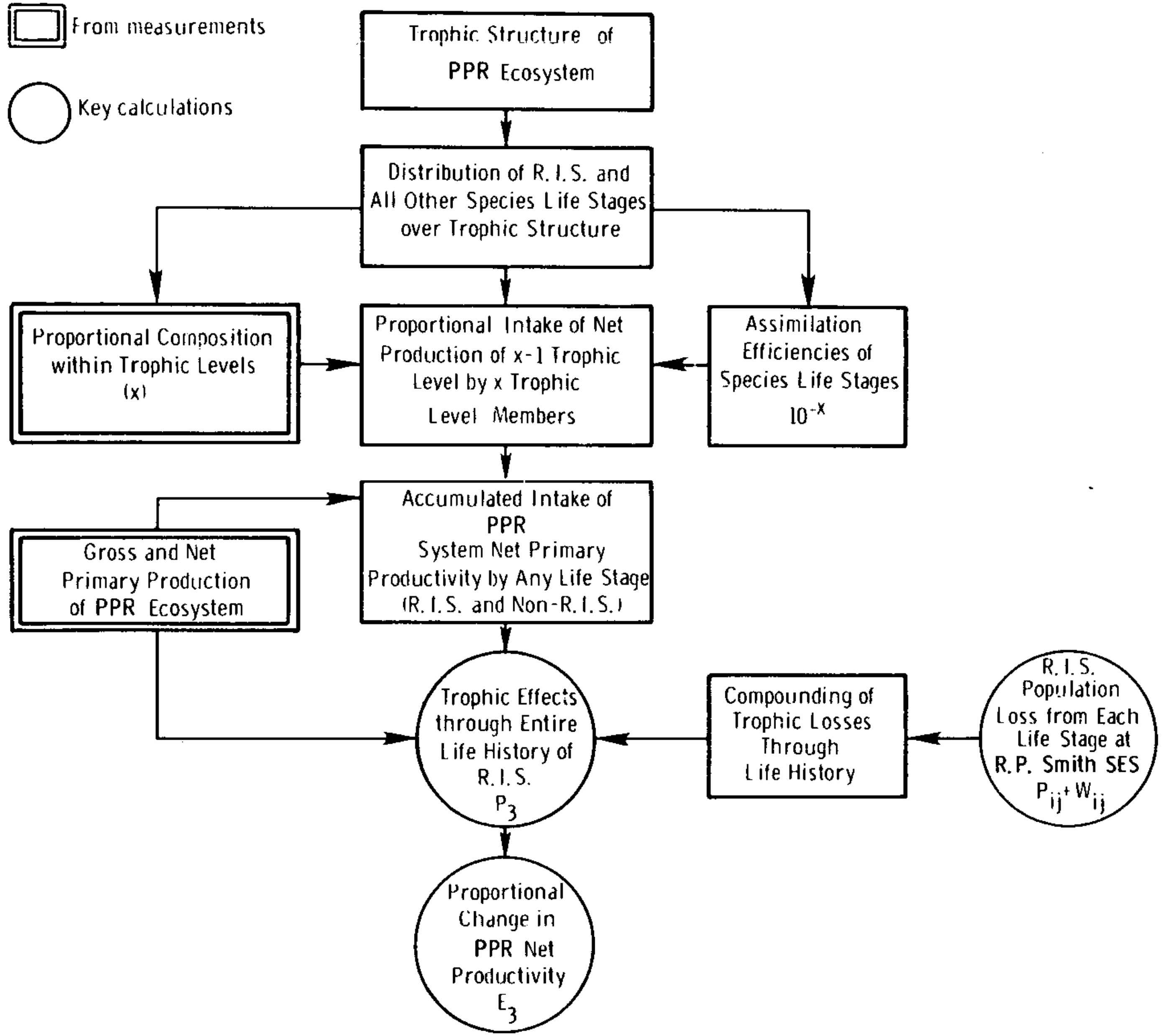

Figure VI-5. General scheme for estimating the ecological impact associated with population losses due to entrainment at R.P. Smith SES on the Appalachian Highlands-Piedmont Potomac River (PPR).

VII. OVERVIEW

This document represents a final assessment of the impact of the R.P. Smith SES on the aquatic biota and processes of the freshwater Potomac River. It summarizes the findings of the many, unrelated studies that have been done at the site and thus provides a relatively clear picture of the manner in which this power plant interacts with the Potomac lotic ecosystem.

Physical findings portray the Potomac River system near Williamsport, MD, as a "typical" temperate, riffle-pool stream characterized by established flow/temperature patterns. The extent to which the operation of the R.P. Smith SES alters these patterns is minimal. The natural stream flow of the region directly above the plant is already affected by a dam built to ensure adequate cooling water. Although the potential effects of the dam were not expressly examined, this structure probably alters sedimentation patterns in this area and benthic community structure. Thermal discharges from the plant influence a well-defined region near the Maryland shoreline. The downstream extent of this thermal perturbation is predominantly controlled by natural stream discharge rates (which, under low flow conditions, may be altered by the dam). The greatest physical effects due to the thermal discharge are in the area directly adjacent to the discharge. In other words, thermal effects should be confined to the discharge region and areas along the Maryland shore directly downstream.

This projection is supported by the findings of the periphyton studies: when effects on community structure, abundance, biomass, or chlorophyll a content were observed at all, they appeared only in regions directly adjacent to the discharge. Consequent analyses of the periphyton studies suggest that care and careful planning are needed when using artificial substrates to quantitatively evaluate thermal effects. They also revealed that although the periphytic communities were similar on different natural substrates (e.g., rock and wood), they often were not similar to those found on artificial substrates. Exposure time of the artificial substrates may be a key variable accounting for the observed differences.

The benthic community probably is a major food source for much of the fish community in the Potomac system. Although this hypothesis was not specifically examined, the preponderance of bottom-feeding fish in the vicinity of the plant strongly support its validity. Benthic community structure or abundance were not adversely affected by cooling system or plume entrainment. Normal plant operations may have enhanced abundances of a few species near the discharge (e.g., through organic enrichment), but the evidence for such a trend is inconsistent. There were generally no adverse effects of thermal exposure on the drift patterns of benthic invertebrates in fall, winter, or spring. Drift patterns during late summer (i.e., August), the period of highest drift densities in northern temperate streams, showed station differences in density and composition. However, these differences could not be consistently related to the water temperature gradient associated with the thermal plume. No studies examined potential secondary plant effects on the benthic population directly, e.g., alterations in growth rates or reproductive success.

Direct plant effects on finfish populations through entrainment or impingement were minimal. Projected annual losses due to these processes are small and are not expected to alter local finfish population levels significantly. The economic and ecological impacts of these losses are estimated to be small also. Plume exposure does not appear to significantly alter finfish growth rates, conditions, or incidence of parasitism/disease. Finfish community composition is not affected by the R.P. Smith thermal discharge plume, but the plume does alter population spatial distributions during winter months. Since significantly more fish, by population or community, are found in the plume areas in winter, the presence of the plume probably enhances survival of certain finfish in winter. At the same time, however, the possibility of large mortality due to cold-shock is increased in cases of plant shutdown.

In sum, the R. Paul Smith SES operation appears to have a limited effect on the upper Potomac River ecosystem. The effect of the dam was not rigorously examined, although some preliminary benthic community composition data showed differences between regions above and below the dam. The downstream effect of plant operations is limited primarily because of the small lateral dimension of the discharge (except under extreme low flow conditions). Thus, most of the downstream river cross sections are not exposed to any thermal perturbation.

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